COMPACT HIGH RESOLUTION IMAGING SPECTROMETER (CHRIS)

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SUMMARY

This paper describes a hyper-spectral imaging system known as CHRIS (Compact High Resolution Imaging Spectrometer) which has been designed for operation on a spaceborne platform. CHRIS is designed to take images of the Earth in multiple spectral bands over the spectral region 415 to 1050nm. Band selection is programmable. The instrument is planned to be launched, in 2001, on an agile small satellite of the 100kg class. This satellite will operate in a sun-synchronous, high inclination orbit with an altitude in then range 700 to 830km. The instrument can provide 19 spectral bands with a spatial sampling interval of 25m at nadir and 37 bands at 50m, at an altitude of 830km. The field of view of CHRIS is 19 km from 830km altitude. Attitude control of the platform will allow access to non-nadir targets, multi-angle observations of selected targets and improved radiometric resolution.

1 INTRODUCTION

Sira Electro-Optics Ltd has completed the development of a hyper-spectral imager known as CHRIS (Compact High Resolution Imaging Spectrometer), to be flown on a small satellite in late 2001. The CHRIS instrument has been designed principally to provide remote sensing data for land applications, although its high spatial resolution provides potential for monitoring applications in littoral region. The CHRIS instrument is scheduled to be flown on a small satellite platform in sun-synchronous polar orbit, at an altitude of in the range 700 to 830km. The candidate platform is a highly manoeuvrable small satellite, capable of large, rapid rotations on pitch and roll axes, with fine control over pitch and roll rates.

2 OBJECTIVES

The observational objective for the CHRIS instrument is to provide data on Earth surface reflectance in the visible/near-infrared (VNIR) spectral band, at high spatial resolution. The instrument will use the platform pointing capabilities to provide Bidirectional Reflectance Distribution Function (BRDF) data (variation in reflectance with view angle) for selected targets on Earth surface. The instrument will be used mainly to provide images of land areas, and will be of interest particularly in recording features of vegetation and aerosols. Interests include observation of littoral regions and validation of techniques for future hyper-spectral imaging missions, particularly with respect to sub-pixel classification techniques.

The technology objective of the instrument is to explore the capabilities of imaging spectrometers on agile small satellite platforms and to provide a demonstration unit for future small satellite missions.

3 CONCEPT

The instrument is an imaging spectrometer, with a "telescope" forming an image of Earth onto the entrance slit of a spectrometer, and an area-array detector at the spectrometer focal plane. The instrument will operate in a push-broom mode during Earth imaging. The detector will be a thinned, back-illuminated, frame-

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transfer CCD. CCD rows will be assigned to separate wavelengths, and CCD columns to separate resolved points in the Earth image.

The platform will be required to provide pointing in both across-track and along-track directions, for target acquisition and for BRDF measurements. The platform will also be required to provide slow pitch during imaging in order to increase the integration time of the instrument. This increase in integration time is needed to achieve the target radiometric resolution, at the baseline spatial and spectral sampling interval.

The spectral waveband covered by the instrument will be limited to the band 415m to 1050nm, which can be achieved using a single CCD area-array detector. The design form selected for the spectrometer is capable of extension to cover the whole spectral range from 415nm to 2500nm by addition of a SWIR detector array.

The instrument will be calibrated in flight, for radiometric response, by use of (a) a dark scene, (c) vicarious techniques and (c) sunlight deflected into the instrument field, through optics of stable transmission and geometrical spread. This will provide data in calibration mode that will be used for flat-fielding and for absolute and relative spectral response measurement. Wavelength calibration will be corrected using data generated in flight from the atmosphere oxygen absorption band at 762nm.

3.1 CHRIS Design

The instrument optical design is shown in figure 3.1-1. The system comprises a catedioptric telescope and an imaging spectrometer. The system has no moving parts.

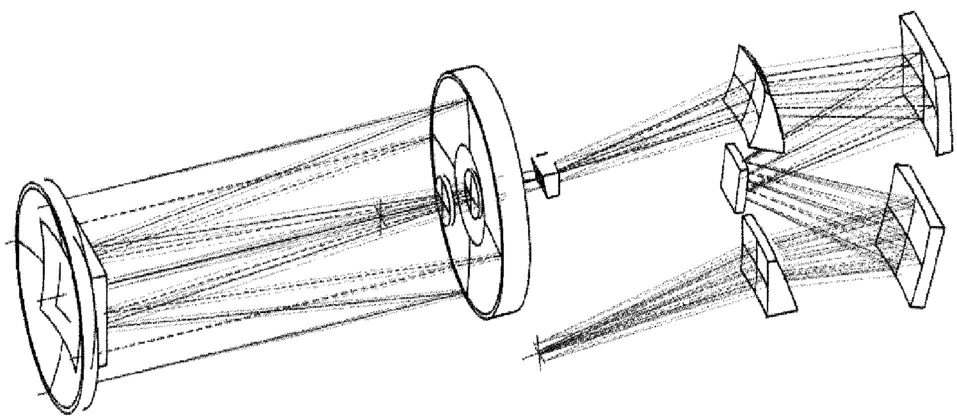

Figure 3.1-1 Instrument optical design

3.2 Telescope

A catedioptric design is utilised for the telescope this provides the required spectral range withoutaspherics or off-axis elements. For an altitude of 830km, the focal length of the system is set at approximately 746mm, and the aperture diameter at 120mm (f/6).

All refracting elements in the present design are made of fused quartz. The secondary mirror, which is cemented to the first large refracting element, is also fused quartz. The telescope primary mirror is made in a common optical glass. This choice is made, in order to athermalise the telescope.

The telescope is axially symmetrical and has only spherical surfaces, so that conventional construction methods can be applied.

3.3 Spectrometer

The spectrometer is a design recently patented by Sira. It uses "prisms" with curved surfaces integrated into a modified Offner relay. The design has only spherical surfaces, and uses only one material - fused quartz - for the prisms. The spectrometer mirrors will be made in a common optical glass. The design, shown in figure 3.1-1, has three mirrors and two curved prisms. As for the telescope, all surfaces are spherical. The dispersion of the spectrometer varies from approximately 1.3 to 12nm across the spectrum with the highest dispersion at 415nm and the lowest in the near infrared at 1050nm.

The spectrometer design will provide registration to better than 5% of the pixel in both spectral and spatial directions, with resolution limited essentially by the detector pixel size.

3.4 Detector

The CCD detector is an MAT (formerly EEV) device. It has the following features:

- CCD area array,
- frame transfer,
- thinned and back-illuminated, (providing good blue response)
- 748 nominal resolved elements per swath width
- 576 lines in exposed region (approx. 200 active for spectral resolution - others used for smear/stray-light correction),
- dump gate (providing fast parallel dumping)

The total frame time for 25m ground sampling is 12.7 ms.

3.5 Electronics

The instrument electronics includes:

- programmed line integration and dumping on chip for spectral band selection
- pixel integration on chip for spatial resolution control
- correlated double sampling (noise reduction circuit)
- dynamic gain switch for optimum usage of the ADC resolution
- 12 bit ADC.

The option for an image buffer exists.

4 OPERATIONAL, PLATFORM & ORBIT ASPECTS

The platform will receive demands from ground control for:

- target location - requiring roll manoeuvres to point across-track
- viewing directions for each target in one orbit - requiring pitch manoeuvres to point along-track,
- spectral bands and spectral sampling interval in each band,
- spatial sampling interval.

The platform will perform the required pitch and roll manoeuvres and transmit control signals to CHRIS to initiate and terminate imaging, with the required spectral and spatial characteristics.

The platform will receive digitised data from CHRIS, store the data in a mass memory unit and transmit to ground on command. Options exist for data compression in a Digital Signal Processing (DSP) unit.

The currently anticipated ground station has a nominal down link of 1 Mbit/s. However, this will be reduced by various link margins. With a single ground station it may take up to three over-passes to down load a set of 5 images (19 km x 19 km) assuming no on-board data compression. Additional ground stations may be used to improve the overall down link.

The platform is currently anticipated to operate at an altitude between 700 and 830 km in a polar and sun-synchronous orbit.

5 CHRIS SPECIFICATION

The provisional specification for CHRIS is as follows:

spatial sampling interval @ 830km	25m (nadir), integration to 50m.
swath width	19 km at nadir
spectral range	410nm to 1050nm
spectral sampling	1.3nm to 12nm
spectral bands	19 band readout @ 25m spatial sampling (nadir) 37 bands readout @ 50m spatial sampling (nadir)
radiance range	albedo 1
radiometric resolution	0.5% @ 20% albedo

The platform is designed to provide across-track and along-track pointing angles of ±30° and ±44° at ground level.

The instrument has an envelope of approximately 200x260x790mm, a mass of less than 14kg and a power consumption of approximately 9W.

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The current plans are to launch on a small satellite provide by the European Space Agency.